AD-A231 370

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	20 November 1990	Technical Paper

4. TITLE AND SUBTITLE

ARC Digitized Raster Graphics and their Application

5. FUNDING NUMBERS

DTIC FILE COPY

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

United Nations
New York, NY

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

DTIC ELECTE JAN 22 1991 S D D

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

(Compact Disc - Read Only Material)

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

ARC Digitized Raster Graphics (ADRG) are digitized replicas of hard copy source maps and charts that the Defense Mapping Agency produces on CD-ROM for distribution.

The ADRG process converts the hard copy source, datum, and projection to WGS84 and the Equal Arc-Second Raster Chart/Map (ARC) projection which permits a worldwide seamless data base for map data of a given scale.

Products currently available are: Operational Navigation Charts (ONC) at 1:1,000,000, Tactical Pilotage Charts (TPC) at 1:500,000, Joint Operations Graphics (JOG) at 1:250,000, Topographic Line Maps (TLM) at 1:50,000 and Jet Navigation Charts at 1:2,000,000. Many are available for public sale.

ADRG data is best suited for use as raster background images for GIS (Geographic Information System) applications. Within DoD, ADRG currently supports the Navy's AV8B program and the Army's Maneuver Control System.

14. SUBJECT TERMS

Raster, CD-ROM, GIS, Scanning

15. NUMBER OF PAGES

10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

Twelfth United Nations Regional
Cartographic Conference for
Asia and the Pacific
Bangkok, 20-28 February 1991

ARC Digitized Raster Graphics and their Application

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Summary

ARC Digitized Raster Graphics (ADRG) are digitized replicas of hard copy source maps and charts that the Defense Mapping Agency produces on Compact Disc-Read Only Material (CD-ROM) for distribution.

The ADRG process converts the hard copy source datum and projection to the World Geodetic System 1984 (WGS-84) and the Equal ARC-Second Raster Chart/Map (ARC) System which permits a worldwide seamless data base for map data of a given scale.

Products currently included are: Operational Navigation Charts (ONCs) at 1:1,000,000, Tactical Pilotage Charts at 1:500,000, Joint Operations Graphics (JOGs) at 1:250,000, Topographic Line Maps (TLMs) at 1:50,000 and Jet Navigation Charts (JNCs) at 1:2,000,000. Many CD-ROMs of small scale maps are available for public scale.

ADRG data is best suited for use as raster background images for geographic information system applications. Within U.S. Department of Defense, ADRG currently supports the Navy's AV8B program and the Army's Maneuver Control System.

ADRG Product Description

Definition

ADRG are digital images derived from printed maps and charts and are distributed on CD-ROM. ADRG is comprised of a raster image of a paper map or chart supported by ancillary raster images of chart-specific marginalia and text data such as datum, projection, and accuracy information.

ADRG raster map images are generated by transforming a scanned map from its original datum and projection to the WGS 84 on the projection defined in the Equal Arc system. Production of ADRG on WGS 84 in the ARC system permits generation of a worldwide seamless image database for maps of the same scale. Currently, ADRG coverage includes JNCs at 1:2,000,000, ONCs at 1:1000,000, TPCs at 1:500,000, and some JOGs at 1:250,000 and TLMs at 1:50,000.

ADRG data is organized into distribution rectangles which are groups of one or more same-scale maps. Distribution rectangle size is limited by the amount of data that will fit on a CD-ROM; the typical size does not exceed 600 megabytes. As a rule, ONCs, TPC, and JNCs are distributed one sheet per CD-ROM; six TLMs and four JOGs fit into a single distribution rectangle. On multi-sheet distribution rectangles, the joins between adjacent sheets are practically undetectable.

ADRG raster image data is collected as nominal 100 micron pixels in 24-bit red, green, and blue color. During the ADRG product design phase, 24-bit color was determined to be high enough resolution to withstand multiple resampling operations without significant image degradation.

For a given CD-ROM, top level data files include a text file describing the distribution rectangles that appear on the disc, as well as a color patch image file to use for color calibration on a user's display system. For a given distribution rectangle, there is a subdirectory containing text files of ancillary data that describe the ARC images, accuracy of the source map, and security/releasability information. The subdirectory also contains the ARC images themselves with the corresponding overview image.

The overview image, compressed from the actual 24-bit ARC image, is designed to fit in its entirety on a single screen display. It is the digital equivalent of a location diagram and provides a graphic index for rapid access to the full-resolution ARC image.

Each source map within a distribution rectangle also has its own complement of ancillary data files. These files include source-specific information such as map name, datum, essential aeronautical data, and map sheet boundary coordinates. Each

source map within a distribution rectangle also has a set of one or more raster images of map-specific marginalia. Examples include landmark feature symbols and boundary diagrams.

ADRG design reflects the Defense Mapping Agency's emphasis on standard exchange formats. All ADRG data and file directories are formatted in compliance with the ISO 8211 standard. International Standards Organization (ISO) 8211 is a self-describing file format flexible enough to accommodate a variety of data formats and is completely independent of the exchange medium. ISO 9660 has been selected as the volume and file structure for the ADRG CD-ROMs.

ARC System

The ARC system was designed for ease of computer display and for simple, direct computation of geographic coordinates from image pixel location.

As implemented in ADRG, ARC defines 16 non-polar bands called zones that lie between 80 degrees north and 80 degrees south latitude plus two additional zones at each pole (Figure 1). In the non-polar zones, ARC is based on an equirectangular projection (Synder, 1987, page 90); the spherical form of the azimuthal equidistant projection, polar aspect (Synder, 1987, page 191) forms the projection basis for the ARC system over the poles. The number of zones defined in ARC minimizes distortion in a given zone to no more than 18 percent maximum stretch or shrink. The datum used for ARC in ADRG is WGS 84).

Although the scale of any given application of the ARC system is dependent upon the scale of the map originally scanned, ARC has a simple relationship to angular distance for a given scale. Within a specified non-polar zone, any pixel represents the same angular distance in the east-west direction. Across zone boundaries in the north-south direction, each pixel represents the same angular distance in all non-polar zones.

ARC was also designed to support creation of seamless worldwide map image databases. As it is applied in ADRG, a 1024 pixel overlap between ARC zones allows programming of image display software to scroll seamlessly from zone to zone.

Pixels in ARC are organized into 128 x 128 pixel tiles. This tiling scheme, which is seamless across the worldwide ARC zones, permits development of optimized image data retrieval software that can access image data rapidly by tile.

ADRG Production Process

Production System

The ADRG production system consists of four 19" monitor color graphics data preparation workstations, one 44" x 60" large format

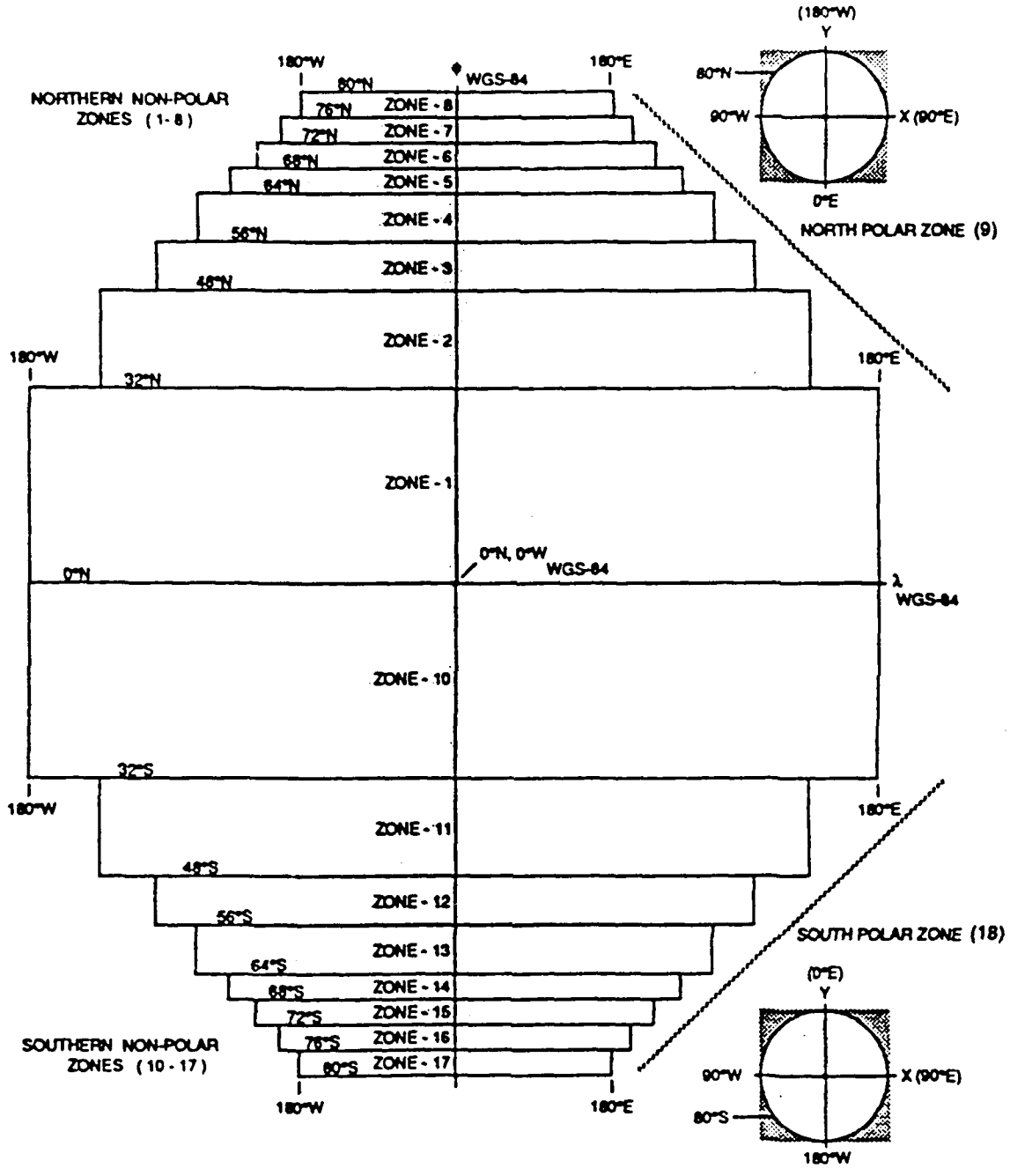

Figure 1. ARC System Zone Layout

drum scanner with interface processor, five transformation batch processors running at 10 million instructions per second with three gigabytes of disk space and 117 megabytes of memory, and two 27" monitor color graphics quality control workstations. All system components are connected to a dedicated network. Once input data is prepared for entry into the ADRG production system, data processing time for each CD-ROM ranges from five to seven hours, depending on the size and type of charts to be distributed on the particular CD-ROM.

Source Preparation

Although ADRG production is highly automated, initial chart preparation and data collection is manual. Cartographers manually update aeronautical charts with Chart Update Manual information to reflect conditions hazardous to navigation. Chart series in which adjacent charts overlap are also examined for any features or labels in an overlap region that need to be moved. Relevant chart parameters such as datum, projection, sheet corner coordinates, graticule spacing, and accuracies are collected from the chart itself and from other databases as text information. Other data collected identifies which marginalia such as boundary diagrams or elevations tint diagrams should also be captured as raster images. All text or ancillary data is entered into a microcomputer database from which a floppy disk is extracted for interface to the ADRG production system.

Processing

The ADRG production flow consists of seven main steps that are summarized in Figure 2. The production process begins with the entry of ancillary data into a data preparation workstation via floppy disk (Step 1). System resources are allocated during this step to ensure availability of adequate disk space for processing and to assist in automated tracking of data files through the production system. In addition, system operations may interactively verify and edit input ancillary data before data processing begins.

Upon completion of the data input process step, required data items are automatically validated and Metric Support Data (MSD) is generated. MSD is a set of polynomial coefficients for rapid transformation from WGS-84 or the ARC system to the source datum or projection for those ADRG users who require map information on its original datum and projection.

In the next process (Step 2), the paper map is mounted for scanning. The scanner collects swaths of 250 lines per inch around the circumference of the scanner drum. The 24-bit red, green, and blue data is deswathed and rotated so that the raster image is in row-major format. The result is a north-up, right-reading data file. During the scanning process, a copy of the

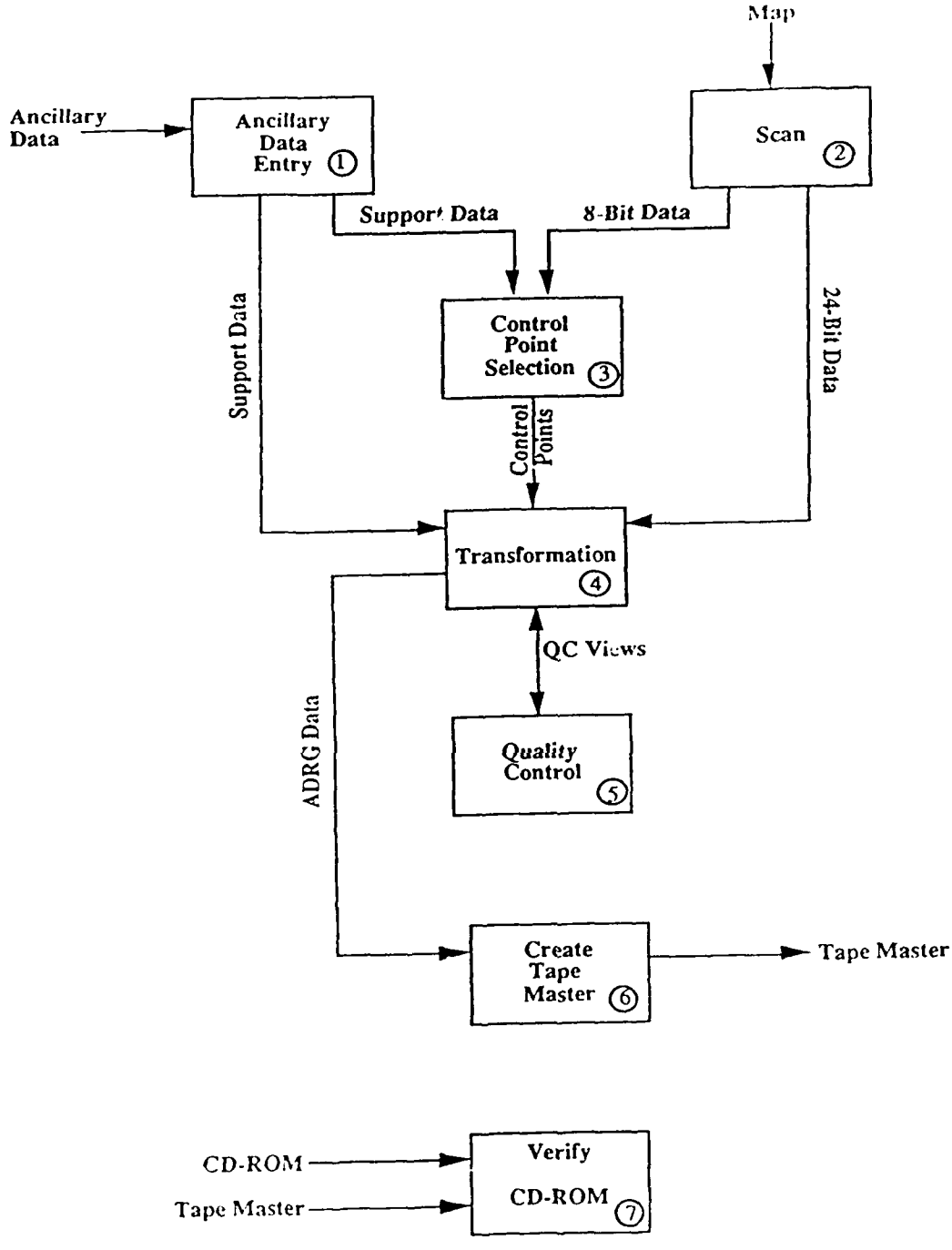

Figure 2. ADRG Production Flow

24-bit color data is condensed to 8-bit color data using a color table. The 24-bit data is sent over the network to a transformation node for later batch processing. The 8-bit data is sent to a data preparation node for control along with a condensed overview of the entire scanned area for use as a working file.

The system operator uses the 8-bit image data to select marginalia to be stored as raster images and to perform map registration (Step 3). Once the legends are selected, the control point selection software automatically generates a list of candidate areas for control using map corners and graticule spacing information defined in the ancillary data. Then the operator ties the geographic coordinates to the scanned image by visually identifying the (row, column) coordinates that represent the four map corners. The software automatically presents to the operator an expanded view of the region surrounding each candidate area for sub-pixel refinement in identifying control points.

As each candidate point is measured, a sequential least squares adjustment is performed and the resulting residuals are displayed to aid the operator in detecting blunders. Once an adequate control solution is achieved, the control information and legend information is saved for the ARC transformation process step.

On the transformation nodes, control and legend information is merged with ancillary data, MSD, and the 24-bit color raster image data (Step 4). The ARC transformation algorithm is based on a single math model that dewarps the hardcopy map, performs the projection transformation to ARC and the datum transformation to WGS-84, and performs color resampling on the resultant pixels all in one step. In addition, the transformation software creates the overview image as a 16:1 spatial compression of the ARC image, modified by black enhancement algorithm to retain the map graticule.

The text and image files are placed in their proper file and directory structure according the ADRG U.S. Military Specification. The final step of the transformation process is formatting the ADRG files according to the ISO 8211 specification. A text data rep and an image tiling rep are then generated for quality control review.

Quality Control

ADRG quality control is performed on a large screen quality control workstation and consists of visual and quantitative checks (Step 5). The quality control cartographer visually reviews all marginalia images. The overview image is used to select a number of views from the full resolution ADRG image. Measurement of geographic graticule and grid intersections are made on the full resolution image. The software computes a measured point's displacement from its theoretically correct position, based on

known characteristics of the geographic graticule or grid. Ninety percent of the measured points must be within two pixels of their correct position.

Manufacturing and Distribution

Once an ADRG data set has passed quality control, an image of the final CD-ROM, including ISO 9660 formatting, is output on a set of nine-track master tapes (Step 6). The tapes are sent to a commercial compact disk manufacturer for mastering and replication. Sample copies of each ADRG CD-ROM title undergo a full or partial bit comparison to the original master tapes (Step 7). For further verification, an ADRG CD-ROM can be read back into a quality control workstation for visual display. After verification, ADRG CD-ROMs are sent to Defense Mapping Agency Combat Support Center, Philadelphia Distribution Center, for worldwide distribution.

ADRG Applications

ADRG is designed to be a raster image database supported by cartographically significant text information that is adaptable to a variety of user-specific applications. The Defense Mapping Agency does not distribute any application software with ADRG CD-ROMs. Sufficient information is available in the U.S. Military Specifications for ADRG (also available through Defense Mapping Agency) to allow applications programmers to access any ADRG data appropriate to a specific user need.

ADRG raster map images are rapidly becoming the background and overview data for a variety of U.S. Department of Defense systems with geographic information systems characteristics. These U.S. Department of Defense systems primarily support mission planning activities, but some applications also support on-board and battle management systems.

One of the earliest ADRG applications was an on-board moving map display for the U.S. Navy AV8B (Harrier) and F/A-18. For this system, the U.S. Navy uses ADRG disks to derive a Compressed Aeronautical Chart which is then used to develop mission-specific flight path images. This ADRG-based product is put on the aircraft as an aid to the pilot. The AV8B and F/A-18 program currently use ADRG coverage of TPC

At the battle management system level, U S. Department of Defense systems use ADRG data to support activities over a specified area.

The U.S. Army's Maneuver Control System (MCS) is a mobile mission planning system for field command. MCS uses a compressed product derived from the ADRG images of existing maps.

The U.S. Navy's Tactical Air Mission Planning System can be based afloat on a land-based command center. ADRG data can be used as a background display for positioning aircraft or ships in a given area.

Joint Operational Tactical System is a command and control battle management system designed for a desktop computer shipboard or ashore. ADRG data will be used experimentally to support this interrogative tactical display system.

ADRG will also support the Navy's shipboard MH-53 mine-sweeping helicopter activity. Helicopters will report satellite Global Positioning System positions of mines to the carrier ship. The mine positions will then be displayed on an ADRG image as the data is collected. Although still in the prototype phase, ADRG coverage of Harbor and Approach and Coastal Charts is intended to support the planned MH-53 activity.

The widest use of ADRG data is for command and control mission planning over large areas.

The Joint Visually Integrated Display System is a fast interrogative tactical display that uses ADRG as a raster background. This system, located at the National Military Command Center, will be used by the Joint Chief of Staff to overlay intelligence information in vector format to support counternarcotics activities. Identical systems support the Drug Enforcement Agency and the Commanders in Chief for counter-narcotics.

The FULCRUM system used by the U.S. Air Force is another geographic information system-like system that supports intelligence and operations planning. FULCRUM can use ADRG data for background images and can exploit other digital mapping products such as Digital Terrain Elevation Data, Digital Feature Analysis Data, and Interim Terrain Data in conjunction with ADRG.

Other mission planning systems intending to use ADRG background raster data include Tactical Air Command's Mission Support System, which will use compressed ADRG data, and Strategic Air Command's Strategic Mission Data Preparation System.

Conclusion

The ADRG production process represents a rapid means of incorporating existing hardcopy maps and charts into the realm of digital processing. As a data base, ADRG is well on the way to providing a wide range of raster background data; there are currently over 1,000 ADRG CD-ROMs available for distribution, many of which are available for public sale. Incorporation of ADRG data into any Geographic Information System is limited only by a user's application software.

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